US008914031B2

(12) **United States Patent**
Cho

(10) **Patent No.: US 8,914,031 B2**

(45) **Date of Patent: Dec. 16, 2014**

(54) **BEAMFORMING APPARATUS AND BEAMFORMING METHOD FOR ANTENNA**

(75) Inventor: **Jeong Hoon Cho**, Seoul (KR)

(73) Assignee: **LG Innotek Co., Ltd.**, Seoul (KR)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 288 days.

(21) Appl. No.: **13/602,860**

(22) Filed: **Sep. 4, 2012**

(65) **Prior Publication Data**

US 2013/0059620 A1 Mar. 7, 2013

(30) **Foreign Application Priority Data**

Sep. 2, 2011 (KR) 10-2011-0089181

(51) **Int. Cl.**
H04W 36/00 (2009.01)
H04W 16/28 (2009.01)
H04W 88/02 (2009.01)

(52) **U.S. Cl.**
CPC ***H04W 16/28*** (2013.01); *H04W 88/02* (2013.01)
USPC **455/437**; 455/524; 455/525; 343/714; 343/723

(58) **Field of Classification Search**
CPC H04W 16/28; H04W 88/02
USPC 455/524, 525, 436, 437; 343/714, 723
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

6,768,913	B1 *	7/2004	Molnar et al.	455/562.1
7,995,468	B2 *	8/2011	Sakai	370/221
8,111,679	B2 *	2/2012	Tsutsui	370/342
8,374,650	B2 *	2/2013	Kotecha et al.	455/561
2006/0223573	A1 *	10/2006	Jalali	455/552.1
2007/0135125	A1 *	6/2007	Kim et al.	455/436
2008/0051150	A1 *	2/2008	Tsutsui	455/562.1
2008/0181174	A1 *	7/2008	Cho	370/329
2009/0092122	A1 *	4/2009	Czaja et al.	370/350
2010/0054121	A1 *	3/2010	Sakai	370/221

FOREIGN PATENT DOCUMENTS

JP	2005-128671 A	5/2005
JP	2006-246338 A	9/2006
JP	2009-164920 A	7/2009

* cited by examiner

Primary Examiner — Dominic E Rego
(74) *Attorney, Agent, or Firm* — Birch, Stewart, Kolasch & Birch, LLP

(57) **ABSTRACT**

Disclosed are a beamforming method and a beamforming apparatus for an adaptive antenna. A mobile terminal equipped with the adaptive antenna is initialized, a base station to transceive a signal with the mobile terminal is searched, beamforming is performed based on the searched base station, a reference position value of the mobile terminal is stored, and the beamforming of the antenna is adjusted if a sensing module in the mobile terminal detects position change of the mobile terminal based on a reference position. A changed position of the mobile terminal is stored as the reference position value, so that the position of the terminal is detected based on the reference position in real time, thereby simply and accurately performing the beamforming.

16 Claims, 4 Drawing Sheets

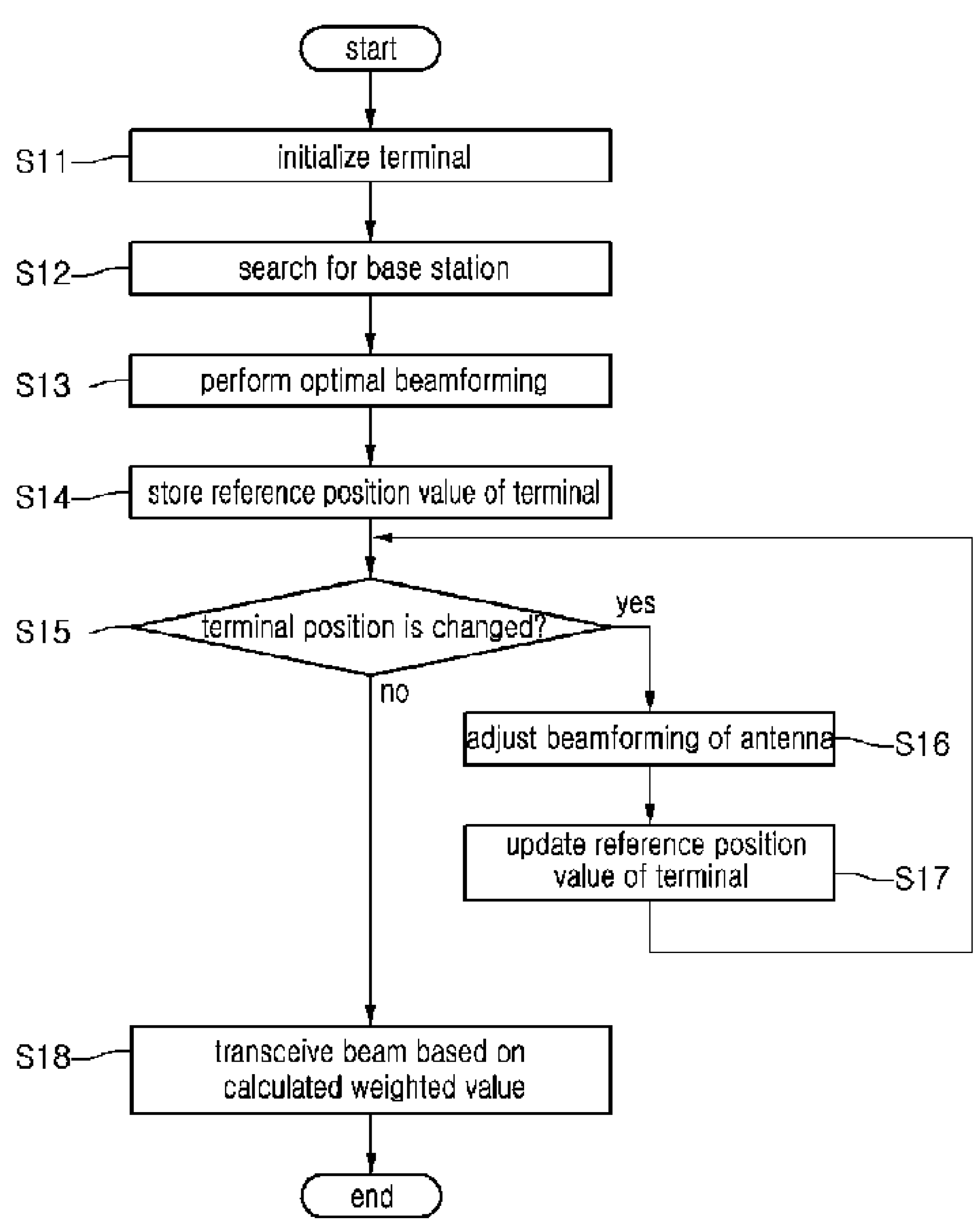


Fig. 1

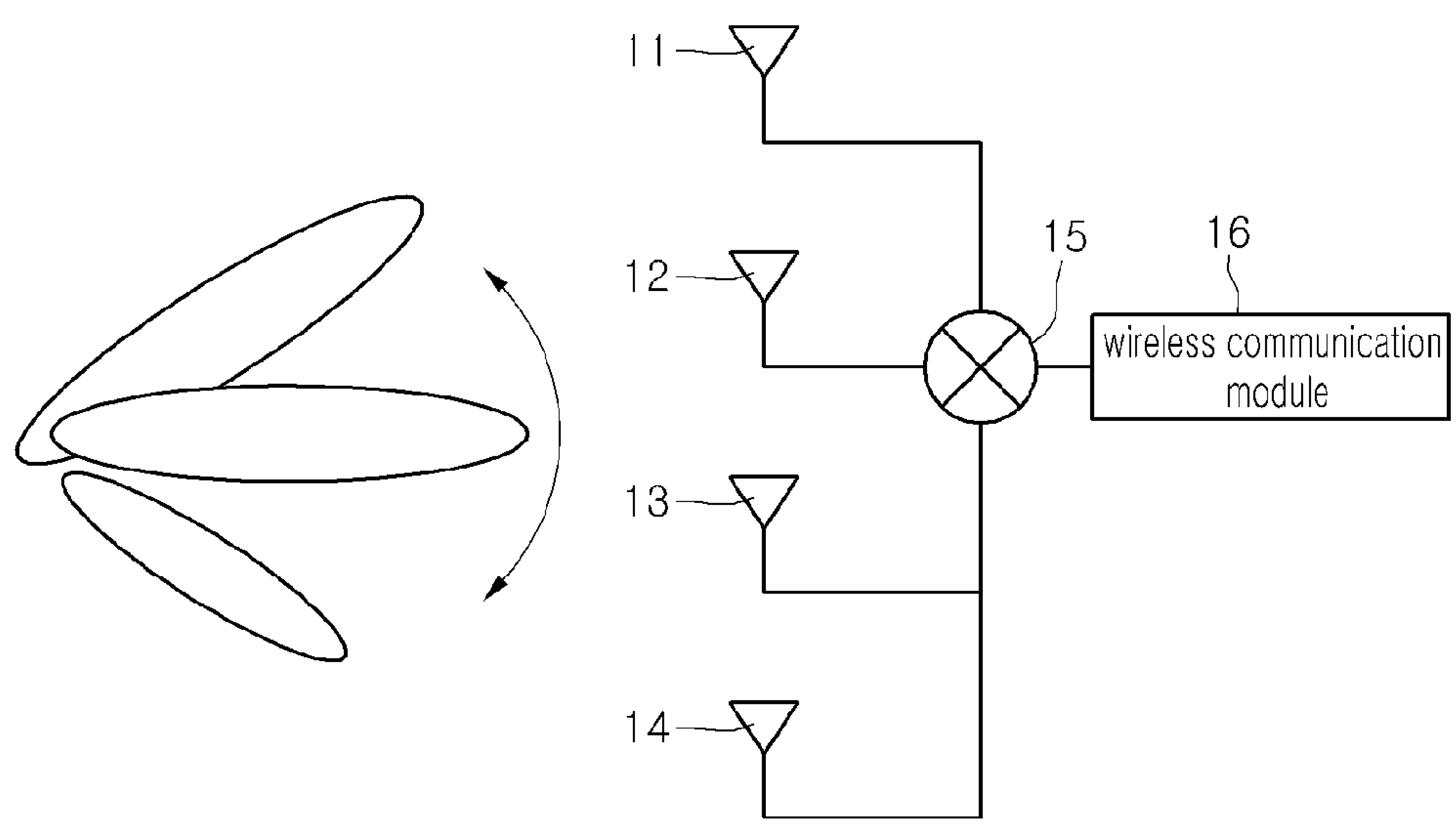


Fig. 2

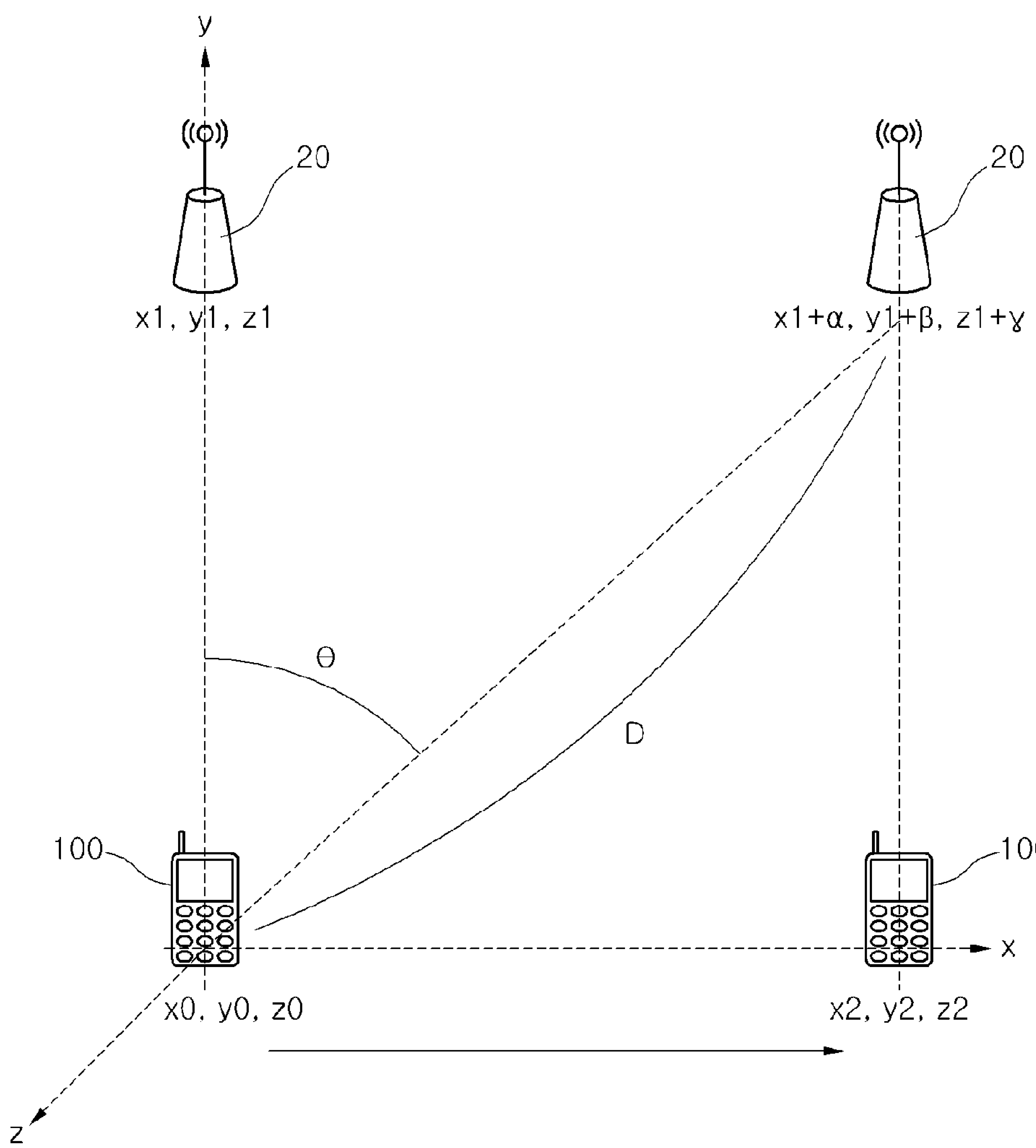


Fig. 3

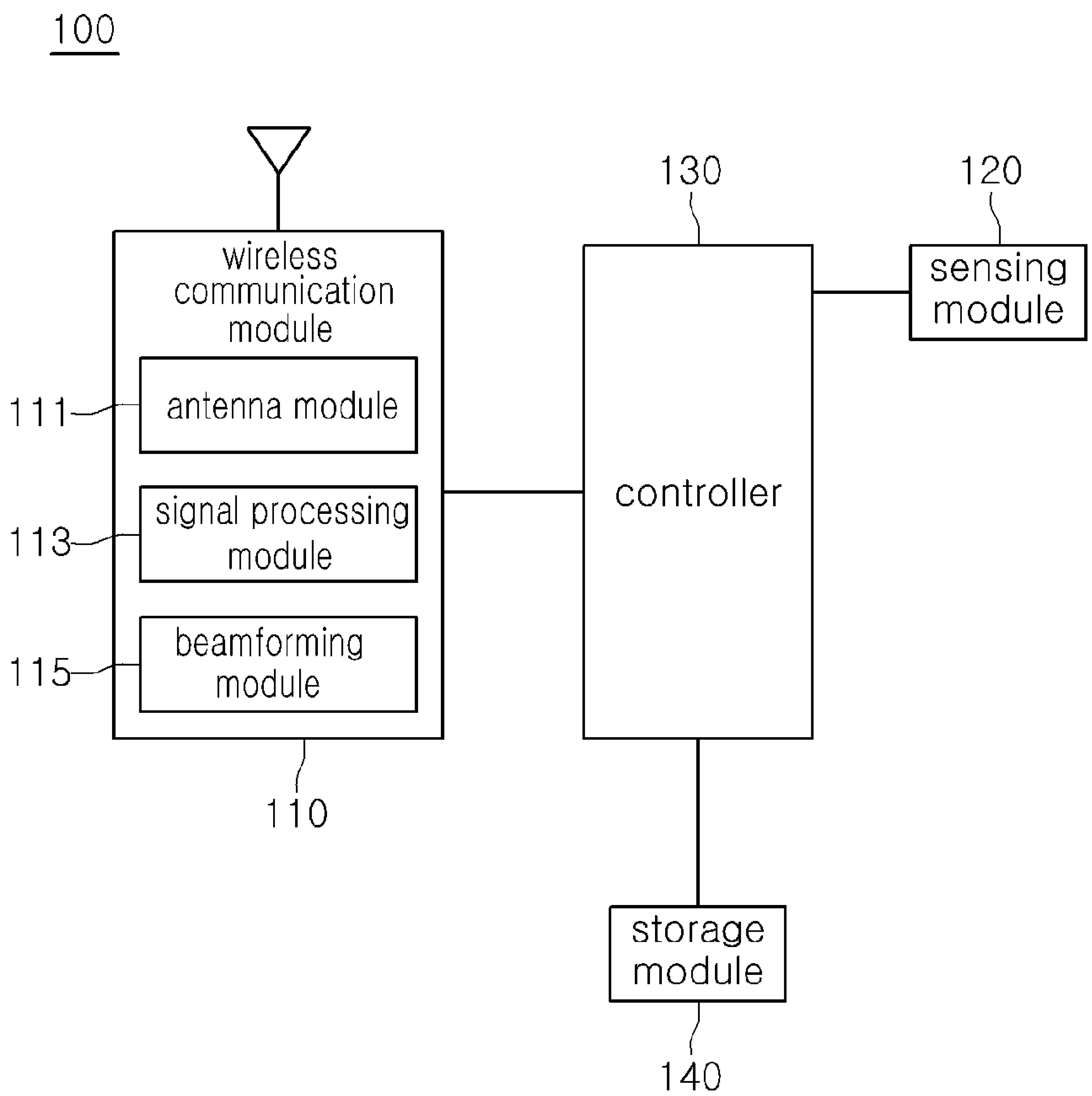
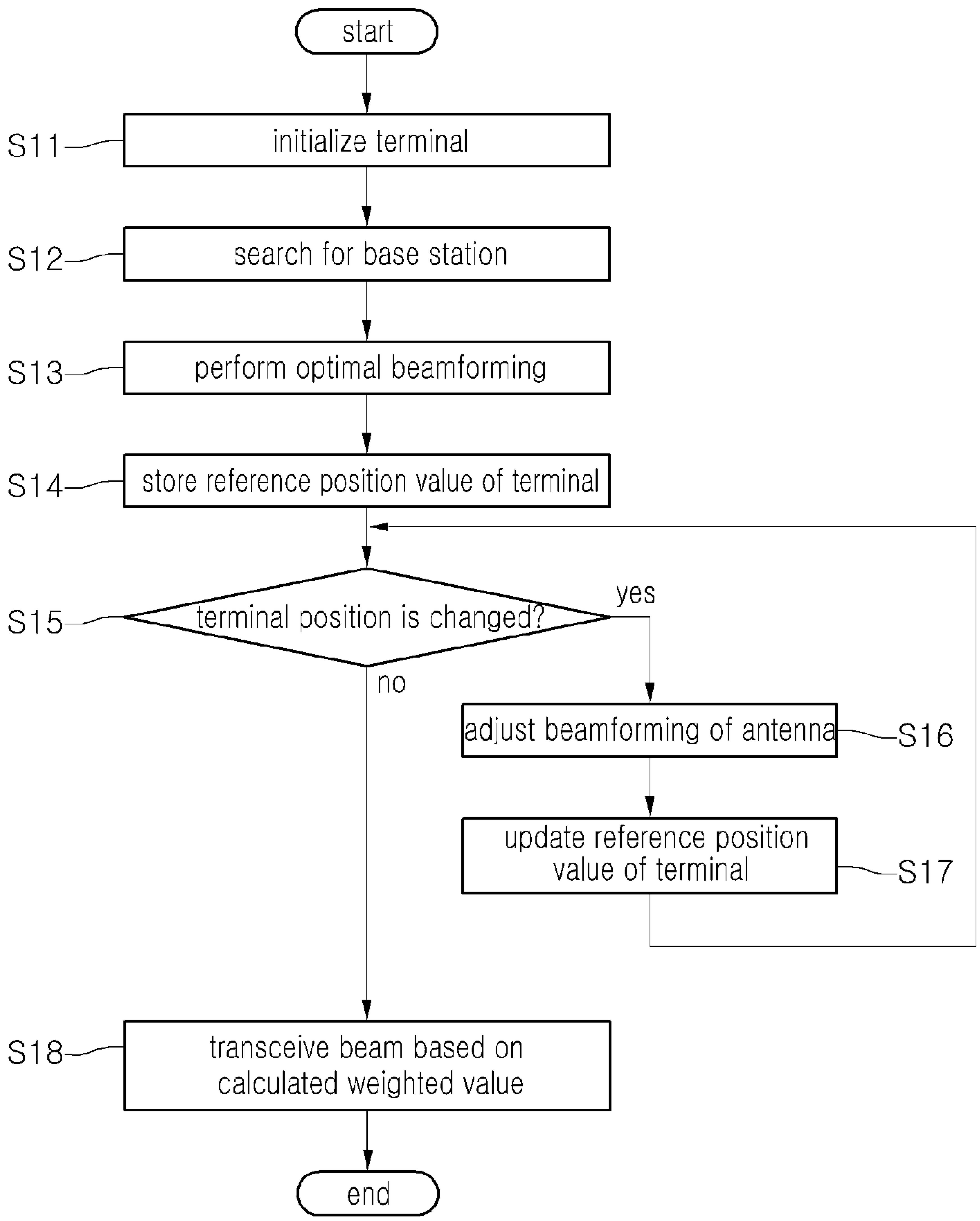

100
wireless communication module
antenna module
signal processing module
beamforming module
111
113
115
110
130
controller
120
sensing module
storage module
140

Fig. 4


start
S11
initialize terminal
S12
search for base station
S13
perform optimal beamforming
S14
store reference position value of terminal
S15
terminal position is changed?
yes
no
adjust beamforming of antenna
S16
update reference position value of terminal
S17
S18
transceive beam based on calculated weighted value
end

BEAMFORMING APPARATUS AND BEAMFORMING METHOD FOR ANTENNA

BACKGROUND

The disclosure relates to a beamforming apparatus and a beamforming method for an antenna. In particular, the disclosure relates to a beamforming apparatus and a beamforming method for an antenna, capable of checking a direction toward a base station in real time by using an inertial sensor of an appliance equipped with an antenna, and optimally correcting beamforming when the position of the base station is changed.

Recently, as communication systems are developed to 3G and 4G communication systems, the development of the optimal antenna has been accelerated according to the diversified channel environments. In addition, a multi-input multi-output (MIMO) scheme for high-rate data transmission and an adaptive MIMO beamforming scheme according to the energy efficiency and a propagation environment have been employed. An adaptive antenna array may be used for a signal received therein from a desirable signal source or a signal received therein from an undesirable or interfered signal source, and beamforming may be performed by setting a weighted value with respect to an individual antenna installed in each antenna array.

Meanwhile, when performing the optimal beamforming by calculating an AOA (angle of arrival), a phase, and an intensity of a signal received from a base station in real time in order to improve the efficiency of the adaptive antenna, a communication load between base stations is caused, a predetermined computation time is required, or a complex algorithm for the computation is required. Accordingly, a beamforming technology to minimize the network load caused by the position change of the terminal is required.

SUMMARY

The disclosure provides a beamforming apparatus and a beamforming for an antenna, capable of reducing a computation time when performing real-time beamforming by mounting an acceleration sensor in a terminal and by performing the beamforming according to the position change of the terminal.

According to the embodiment, there is provided a beamforming method for an adaptive antenna, which includes initializing a mobile terminal equipped with the adaptive antenna, searching for a base station to transceive a signal with the mobile terminal, performing beamforming based on the searched base station, storing a reference position value of the mobile terminal, and adjusting the beamforming of the antenna if a sensing module in the mobile terminal detects position change of the mobile terminal based on a reference position.

According to the embodiment, there is provided a beamforming apparatus for an adaptive antenna. The beamforming antenna includes a controller of initializing a mobile terminal equipped with the adaptive antenna, a wireless communication module of searching for a base station to transceive a signal with the mobile terminal, and a sensing module of detecting position change of the mobile terminal. The wireless communication module performs beamforming suitable for the transceiving of the signal and adjusts the beamforming of the antenna according to the position change of the mobile terminal.

According to the disclosure, the beamforming of an antenna can be effectively performed through simple computation and communication.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a block diagram showing a beamforming method for an adaptive antenna;

FIG. **2** is a view showing a beamforming angle according to the position change of a terminal;

FIG. **3** is a block diagram showing the structure of a beamforming apparatus according to one embodiment of the disclosure; and

FIG. **4** is a flowchart showing the beamforming method according to one embodiment of the disclosure.

DETAILED DESCRIPTION OF THE EMBODIMENTS

FIG. **1** is a block diagram showing a beamforming method for an adaptive antenna. Referring to FIG. **1**, the adaptive antenna may include an antenna array including a plurality of antennas **11**, **12**, **13**, and **14**, a circuit **15** to combine signals received therein from the antenna, and a wireless communication module **16**. The wireless communication module **16** may include a frequency down converter (not shown) to convert a high frequency signal received therein from the antenna array into a baseband signal, an A/D converter to convert an analog signal to a digital signal, and a beam former which measures the intensities, phases, and angles of arrival of signals arrived therein through various paths to perform a time-space process for the purpose of beamforming and to apply a weighted value to each antenna through a beamforming algorithm. Meanwhile, the weighted value applied to the beam former may be provided in the form of a vector having a dimension corresponding to the number of antennas constituting each antenna array. To this end, various beamforming algorithms may be used. The disclosure provides a beamforming method and a beamforming apparatus, capable of detecting the position change of an antenna and correcting beamforming based on the detected position change of the antenna. The beamforming apparatus according to one embodiment of the disclosure may be applied to a mobile terminal equipped with an adaptive antenna, a smart phone, a cellular phone, and a satellite phone.

FIG. **2** is a view showing the calculation of a beamforming angle according to the position change of a terminal. Hereinafter, a case in which the beamforming apparatus according to one embodiment of the disclosure is applied to a mobile terminal **100** equipped with an adaptive antenna will be described with reference to FIG. **2**.

The mobile terminal **100** searches for the position of a base station **20** by using an antenna installed in the mobile terminal **100**. The mobile terminal **100** may first initialize each module of the mobile terminal **100** after the power of the mobile terminal **100** has been turned on. The mobile terminal **100** initializes the modules by applying power to the antenna and a sensing module and checking the states of the modules.

Next, the mobile terminal **100** searches for the base station **20** at a reference position (x0, y0, z0). When detecting the base station **20** in the state that appliance initialization is performed, the position of the base station **20** about the mobile terminal **100** may be detected at an initial position (x1, y1, z1). The mobile terminal **100** performs the beamforming, which is optimized to transceive signals with the base station **20**, on the basis of the base station **20** positioned at the initial position (x1, y1, z1). The beamforming may be performed by calculating a weighted value vector of each antenna based on the direction of the base station **20** as described above.

The mobile terminal **100** stores the reference position (x0, y0, z0) at which the beamforming is optimized.

Meanwhile, when the mobile terminal **100** relatively moves with respect to the base station **20**, that is, the relative position between the mobile terminal **100** and the base station **20** is changed, the position of the base station **20** may be detected based on the mobile terminal **100**. For example, when the initial position (x1, y1, z1) of the base station **20** is shifted to the position (x1+α, y1+β, z1+γ), the mobile terminal **100** must adjust the existing beamforming in relation to the base station **20**. The changed position (x1+α, y1+β, z1+γ) of the base station **20** may be detected by using a gyro sensor installed in the mobile terminal **100**. The position of the base station **20** may be set based on the relative position shift of the mobile terminal **100**, and may be defined on a sphere about the mobile terminal **100**. FIG. **2** shows the position of the base station **20** on the spherical surface having a radius of D. The initial position (x0, y0, z0) of the mobile terminal **100** corresponds to the initial position (x1, y1, z1) of the base station **20**. In addition, the relative position (x2, y2, z2) of the mobile terminal may be expressed as the position (x1+α, y1+β, z1+γ) of the base station **200**. When the position of the base station **20** is changed, the direction of the base station **20** may be calculated as a direction inclined at an angle of θ from the initial position (x1, y1, z1). The angle θ for the direction of the base station **20** may be defined as following Equation 1.

In this case, the radius D of the sphere is 1, and α, β, and γ serving as output values of the gyro sensor are in the range of −1 and 1.

$$\theta = \cos^{-1}\frac{2D^2 - (\alpha^2 + \beta^2 + \gamma^2)}{2D^2} \qquad \text{Equation 1}$$

The mobile terminal **100** may periodically repeat a series of processes of updating the reference position of the mobile terminal **100** to the position (x2, y2, z2), searching for the position of the base station **20** by using the updated reference position (x2, y2, z2), and modifying the beamforming and updating the reference position of the mobile terminal **100** if the position of the base station **20** is changed, that is, if the position of the mobile terminal **100** is changed. Accordingly, the computation amount and the computation time for the beamforming can be more reduced as compared with the conventional beamforming scheme based on the signal transceiving between the mobile terminal **100** and the base station **20**.

FIG. **3** is a block diagram showing the structure of a beamforming apparatus according to one embodiment of the disclosure. Referring to FIG. **3**, the beamforming apparatus according to one embodiment of the disclosure may be realized as the mobile terminal **100**. The mobile terminal **100** may include a wireless communication module **110** to transceive signals with the base station **20**, a sensing module **120** to periodically detect the position change of the mobile terminal **100**, a controller **130** to initialize the mobile terminal **100** and calculate a beamforming angle based on the reference position of the mobile terminal **100**, and a storage module **140** to store the reference position of the mobile terminal **100** and the changed position of the mobile terminal **100**.

The wireless communication module **110** may include an antenna module **111** used to transceive signals with the base station **20**, a signal processing module **113** including a converter frequency transforming converter to convert signals transceived from the antenna through analog-to-digital converting or digital-to-analog converting, and a beamforming module **115** to calculate a weighted value vector of each antenna of an adaptive antenna.

The sensing module **120** may include a gyro sensor to detect the position change of the mobile terminal **100**.

The controller **130** can perform a series of operations to initialize the mobile terminal **100**, detect the changed position of the mobile terminal **100** in real time, and calculate the weighted value of an antenna array by using the changed position of the mobile terminal **100** as a reference position.

The storage module **140** may store a reference position value of the mobile terminal **100**, a weighted value vector of each antenna included in the antenna array, and data required for the beamforming algorithm used to calculate the weighted value vector. In addition, if the position of the mobile terminal **100** is changed, the storage module **140** may store the changed position of the mobile terminal **100** as an updated position.

FIG. **4** is a flowchart showing a beamforming method according to one embodiment of the disclosure.

In step **S11**, the mobile terminal **100** is initialized.

In step **S12**, the wireless communication module searches for the base station **20**.

In step **S13**, if the base station **20** has been searched, the mobile terminal performs beamforming so that the signal transceiving is optimized with respect to the related base station.

In step **S14**, the reference position value of the mobile terminal **100** is stored in the state that the optimal beamforming is performed.

In step **S15**, a check is made regarding if the position of the mobile terminal is changed. The check regarding if the position of the mobile terminal is changed may be made at a predetermined period, for example, 1 second. If the position of the terminal is not changed, the position change of the mobile terminal is checked when the next period comes, so that the beamforming between the mobile terminal and the base station can be maintained in real time.

In step **S16**, the antenna beamforming is adjusted based on the changed position value of the mobile terminal. The beamforming of the antenna may include calculating a weighted value vector of each antenna to constantly maintain beamforming between base stations based on the changed position of the mobile terminal.

In step **S17**, the changed position of the terminal is stored as the reference position value. In other words, the reference position value of the mobile terminal is changed.

Even after the changed position of the terminal is stored as the reference position value in step **S17**, the position change of the mobile terminal is checked in real time (step **S15**). If the position is changed, operations of changing the beamforming (step **S16**) and updating the reference position value (step **S17**) may be repeated. In other words, operations in steps **S15** to **S17** of frequently checking the position change of the mobile terminal, adjusting the beamforming of the antenna, and updating the changed position as the reference position value may be repeatedly performed.

In step **S18**, if a determination is made in step **S15** that the position of the terminal is not changed, a beam pattern is formed based on a previously calculated weighted value, and the beam is transmitted to the base station. In other words, if the position of the terminal is not changed, the beamforming method according to one embodiment of the disclosure is ended.

As described above, the beamforming method, which can be performed in the mobile terminal, and the beamforming apparatus have been described. The disclosure is not limited to the above embodiment, but applicable to a device provided thereon with a sensor, which can detect the position thereof, and an antenna.

As described above, according to one embodiment of the disclosure, the beamforming of the antenna can be effectively performed by using the simple computation and the simple communication.

Any reference in this specification to "one embodiment," "an embodiment," "example embodiment," etc., means that a particular feature, structure, or characteristic described in connection with the embodiment is included in at least one embodiment of the invention. The appearances of such phrases in various places in the specification are not necessarily all referring to the same embodiment. Further, when a particular feature, structure, or characteristic is described in connection with any embodiment, it is submitted that it is within the purview of one skilled in the art to effect such feature, structure, or characteristic in connection with other ones of the embodiments.

Although embodiments have been described with reference to a number of illustrative embodiments thereof, it should be understood that numerous other modifications and embodiments can be devised by those skilled in the art that will fall within the spirit and scope of the principles of this disclosure. More particularly, various variations and modifications are possible in the component parts and/or arrangements of the subject combination arrangement within the scope of the disclosure, the drawings and the appended claims. In addition to variations and modifications in the component parts and/or arrangements, alternative uses will also be apparent to those skilled in the art.

What is claimed is:

1. A beamforming method for an adaptive antenna, the beamforming method comprising:
- initializing a mobile terminal equipped with the adaptive antenna;
- searching for a base station to transceive a signal with the mobile terminal;
- performing beamforming based on the searched base station;
- storing a reference position value of the mobile terminal; and
- adjusting the beamforming of the antenna if a sensing module in the mobile terminal detects position change of the mobile terminal based on a reference position.

2. The beamforming method of claim **1**, further comprising storing a changed position of the mobile terminal as the reference position value.

3. The beamforming method of claim **1**, wherein the position change is detected by gyroa gyro sensor mounted on the mobile terminal at a predetermined period.

4. The beamforming method of claim **3**, further comprising calculating a beamforming angle of the adaptive antenna by using a detected position change value.

5. The beamforming method of claim **4**, wherein, in the adjusting of the beamforming of the antenna if the sensing module in the mobile terminal detects the position change of the mobile terminal based on the reference position, movement of the mobile terminal is determined as relative movement of the base station.

6. The beamforming method of claim **5**, wherein the base station is positioned on a sphere about the mobile terminal.

7. The beamforming method of claim **6**, wherein the beamforming angle satisfies an equation,

$$\theta = \cos^{-1}\frac{2D^2 - (\alpha^2 + \beta^2 + \gamma^2)}{2D^2},$$

in which D refers to a radius of the sphere and α, β, and γ refer to output values of the gyrogyro sensor.

8. The beamforming method of claim **7**, wherein the α, β, and γ have values in a range of −1 to 1.

9. A beamforming apparatus for an adaptive antenna, the beamforming antenna comprising:
- a controller of initializing a mobile terminal equipped with the adaptive antenna;
- a wireless communication module of searching for a base station to transceive a signal with the mobile terminal; and
- a sensing module of detecting position change of the mobile terminal,
- wherein the wireless communication module performs beamforming suitable for the transceiving of the signal and adjusts the beamforming of the antenna according to the position change of the mobile terminal.

10. The beamforming apparatus of claim **9**, wherein the controller stores a changed position of the mobile terminal as a reference position value.

11. The beamforming apparatus of claim **10**, wherein the sensing modules detects the position change of the mobile terminal at a predetermined period.

12. The beamforming apparatus of claim **11**, wherein the controller calculates a beamforming angle of the adaptive antenna by using a detected position change value.

13. The beamforming apparatus of claim **12**, wherein the controller determines movement of the mobile terminal as relative movement of the base station.

14. The beamforming apparatus of claim **13**, wherein the controller determines that the base station is positioned on a sphere about the mobile terminal.

15. The beamforming apparatus of claim **14**, wherein the beamforming angle satisfies an equation,

$$\theta = \cos^{-1}\frac{2D^2 - (\alpha^2 + \beta^2 + \gamma^2)}{2D^2},$$

in which D refers to a radius of the sphere and α, β, and γ refer to output values of the gyrogyro sensor.

16. The beamforming apparatus of claim **15**, wherein the α, β, and γ have values in a range of −1 to 1.

* * * * *